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(54) Nonuniform probability reel stop mechanism for gaming machines.

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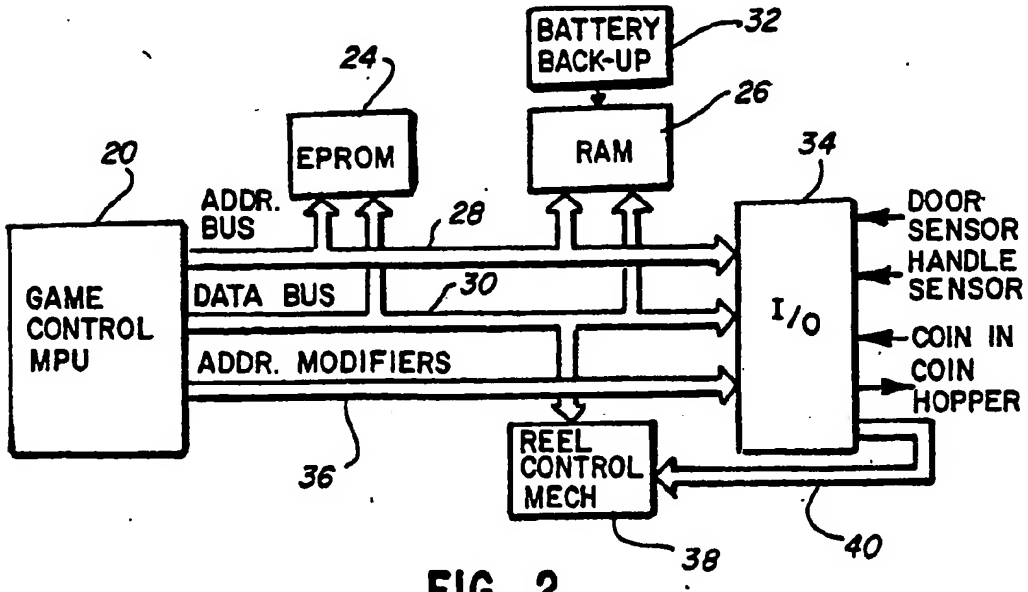

FIG. 2

EP 0 338 743 A2

NONUNIFORM PROBABILITY REEL STOP MECHANISM FOR GAMING MACHINES

Technical Field

The invention relates to the field of gaming devices having rotating reels and more particularly to mechanisms for stopping the reels where the probability of a reel stopping at any one stop is nonuniform.

Background of the Invention

In most reel type gaming machines the symbol bearing reels have an equal probability of stopping at each of the reel stops. This effectively limits the maximum payout for the machine due to the fact that physical size constraints limit the number of reels along with the number of symbols that can be placed on a reel. As an illustration, assume a three reel machine where each reel has 22 symbols and a single reel stop for each symbol with one maximum win symbol on each reel. Then with the reels having an equal probability of stopping at any one stop, the probability of having all three maximum win symbols stop at a win position is 1/22 x 1/22 x 1/22 or 1/10,648. Thus assuming no other winning combinations of symbols are permitted the maximum payout for a dollar machine would be $10,648. As a practical matter, many other winning combinations are desirable in order to maintain player interest in the game so that the actual maximum payout is considerably reduced from this figure.

One approach to solving this problem is to provide reels having two reel stops located very close together for certain symbols on the reels. In this case, the symbols having two reel stops have twice the probability of being stopped in a winning position thus effectively decreasing the odds that a symbol with only one reel stop will appear in the winning position.

Another approach uses the virtual reel concept as disclosed in U. S. Patents 4,448,419 and 4,711,451. In a microprocessor controlled virtual reel machine a virtual reel having more stops than the physical reel is placed into memory. The virtual reel is mapped into the physical reel. The microprocessor selects at random one of the stops in the virtual reel and then stops the reel at the physical reel stop corresponding to the randomly selected position in the virtual reel. In this manner it is possible to provide a machine having reels that will proportionately stop at some physical reel stops more than at others.

In U. S. Patent 3,580,581 another approach is disclosed where a series of capacitive resistor circuits are used to control a counter which in turn selects a reel stop. The values of the capacitive resistive circuits may be adjusted to provide for varying time constants for incrementing the counter resulting in a nonuniform probability that any one reel stop will be selected.

Each of the above approaches has disadvantages including limited flexibility in programming win odds in the two stop per symbol and the virtual reel methods and complicated and difficult to maintain circuitry in the counter approach.

The Invention

The invention provides a nonuniform probability reel stop mechanism for a gaming machine comprising a digital memory for storing a stop index for each reel stop, and a microprocessor for randomly selecting a stop index value including means for predetermining the probability of selection of each of the stop indexes.

Substantial variations in probability of selection of each stop can be provided. The probability of selection of each value of the stop index corresponds to a desired probability of a reel stopping at a predetermined location and the microprocessor is effective to stop the reel at the predetermined positions corresponding to the stop index value selected.

The memory may comprise an array of randomly selected values partitioned into groups or subintervals of values where each group corresponds to a stop index that in turn corresponds to a stop position on a reel. The range of values in each subinterval correspond to a desired probability of the reel stopping at the stop index value corresponding to that stop position on the reel.

The memory stores a probabilty factor associated with each reel stop index. A processor preferably generates a probability value which is then compared to the probability factor associated with the current stop index. If the probability value is greater than the probability factor, the probability factor is subtracted from the probability value resulting in a new probability value and the reel stop is incremented. This comparison process is repeated until the probability value is equal or less than the probability factor. On a

periodic basis a new probability value is selected and the comparison process is repeated. The value of the stop index when a player pulls the handle of the machine is used to stop the reel. The probability factors are selected to provide for varying the times for incrementing the stop index resulting in a predetermined but nonuniform probability that any one reel stop will be selected.

DRAWINGS

FIG. 1 is a perspective view of a reel-type gaming apparatus;

FIG. 2 is a block diagram of the electronic control circuit for gaming apparatus of FIG. 1;

FIG. 3 is a flow chart illustrating reel stop control logic for the chart of FIG. 3;

FIG. 4 is a flow chart illustrating control logic for selecting the upper and lower limits for the partitions of the chart of FIG. 5;

FIG. 5 is a chart illustrating the stopping probability for each reel position for an embodiment of the invention using a memory array of randomly selected values partitioned into groups of stop index values;

FIG. 6 is an illustration of a probability factor array in the memory of FIG. 1; and

FIG. 7 is a flow chart illustrating the operation of the second embodiment of the invention using the array of FIG. 6.

Best Mode

A gaming apparatus 10 employing the embodiment of the invention is shown in FIG. 1. The gaming apparatus 10 includes three symbol bearing reels 12, 13 and 14 within a housing 15 which are caused to rotate in response to a player actuated handle 16 after a coin is inserted into a coin input slot 18.

The gaming apparatus 10 includes a game control microprocessor 20, as shown in FIG. 2, which stops each of the reels 12-14 to display three randomly selected symbols along win lines. If the symbols displayed along the win lines form a winning combination, the microprocessor 20 causes a coin hopper (not shown) to payout, through a payout chute 22 a number of coins or tokens.

The game control microprocessor 20, shown in FIG. 2, is preferably a Motorola 68000 processor. The processor 20 controls the operation of the gaming apparatus 10 in accordance with programs and data stored in an EPROM 24 and RAM 26. The EPROM 24 and RAM 26 are coupled to the processor 20 by an address bus 28 and a data bus 30. To ensure that no data stored in the RAM 26 is lost during a power failure, the RAM 26 is coupled to a battery backup circuit 32. The game control microprocessor 20 is also coupled to various input sensors and apparatus as well as the coin hopper through an input/output board 34 which is coupled to the processor 20 through the address and data buses 28 and 30 and an address modifier line 36. In order to address the input/output board 34, the game control processor 20 must output the correct address modifiers for the input/output board on line 36 as well as the address for the input/output board 34 on the address bus 28. The game control micro-processor 20 controls each of the reels 12-14 through a reel control mechanism 38 which is coupled to the data bus 30. The reel control mechanism 38 includes a stepper motor or the like for each of the reels 12-14 to start and stop the rotation of the reels in accordance with the data on bus 30 from the game control microprocessor 20. The reel control mechanism is also coupled to the input/output board 34 which is responsive to the microprocessor 20 for selecting a particular one of the stepper motor controls to receive data from the bus 30.

In a first embodiment of the invention a portion of the EPROM memory 24 contains a stopping probability array for each of the reels 12-14. Each array is divided into partitions or subintervals where each subinterval defines a range of randomly selected values. There is one subinterval X for each reel stop. In this embodiment of the invention the values of the randomly selected values range from 0.000000 to 1.000000 and the range of values in each subinterval are proportional to the desired probability of the reel stopping at the reel stop associated with the subinterval. This concept for a 20 stop reel is illustrated in the Table I reproduced below:

TABLE I

REEL POSITION X	STOPPING PROBABILITY	SUBINTERVAL LOWER LIMIT	SUBINTERVAL UPPER LIMIT
1	0.010101	0.000000	0.010101
2	0.020000	0.010101	0.030101
3	0.030000	0.030101	0.060101
4	0.040000	0.060101	0.100101
5	0.050000	0.100101	0.150101
6	0.060000	0.150101	0.210101
7	0.070000	0.210101	0.280101
8	0.080000	0.280101	0.360101
9	0.089899	0.360101	0.450000
10	0.050000	0.450000	0.500000
11	0.050000	0.500000	0.550000
12	0.050000	0.550000	0.600000
13	0.050000	0.600000	0.650000
14	0.050000	0.650000	0.700000
15	0.050000	0.700000	0.750000
16	0.050000	0.750000	0.800000
17	0.050000	0.800000	0.850000
18	0.050000	0.850000	0.900000
19	0.050000	0.900000	0.950000
20	0.050000	0.950000	1.000000

The subinterval limits of Table I are stored in the previously mentioned array along with the subintervals X.

Operational logic of this reel stop scheme is illustrated by the flow chart of FIG. 3. As shown in the first logic stop 42 a uniformly random value is generated by the processor 20 having a value between zero and 1.00000. Then at 44 the partition or subinterval X in which the randomly generated value resides is determined from the array of Table I. Once the subinterval containing the randomly generated value has been identified, the processor 20 causes the reel control mechanism 38 at step 46 to stop the reel 12, 13 or 14 in the predetermined position corresponding to the subinterval or stop index X.

As indicated above the range of values in each subinterval of the array corresponds to the probability that the reel 12, 13 or 14 will stop at the reel stop corresponding to the subinterval. In FIG. 4 logic is presented for generating in memory 24 or 26 the subinterval limits that will produce the desired stopping probabilities. In the first step 50 X is initialized to 1 and at 52 the lower limit of the first subinterval is set to zero and the upper limit of the first subinterval is set equal to the desired stopping probability for that subinterval. Then shown at 54 a recursive routine is entered where X is incremented by 1, and at 56 the lower limit of the new value for X is set equal to the upper limit for the preceding value of X. The upper limit for the subinterval of the new value of X is made equal at 58 to the value of the lower limit plus the desired stopping probability for X. As shown at 60 the routine continues until X equals the number of reel stops in the apparatus. In this manner a nonuniform reel stop probability mechanism as illustrated by the chart of FIG. 5 can be created. It will be appreciated that the approach discussed above can provide almost unlimited flexibility in designing a reel type gaming apparatus where the probability of the reel stopping at each reel stop can be adjusted to virtually any desired level.

In a second embodiment of the invention a portion of non-volatile memory either the EPROM 24 or RAM 26 is configured into an array 62 as shown in FIG. 6 for each reel 12-14 in the apparatus 10. Each element of the array 62 contains a probability factor W_i where i denotes a stop index. There will be a value of i corresponding to each programmed stop for the reels 12-14. For example, if a reel has 24 stops, the value of i will range from 1 to 24 where the subscript p denotes the last or maximum number of reel stops. Thus there will be p elements having probability factor W_i in each array 62.

Operation of the second embodiment of the invention for an individual reel of the apparatus 10 is illustrated by the flow chart of FIG. 7. For each reel 12-14, the processor 20 will perform the logic of FIG. 7. When the apparatus 10 is initially powered up as indicated at 64, the processor 20 will set the value of i equal to 1 as shown at 66. The initialization process also includes at 68 the setting of a residual probability value W_c to the value of W_i.

The actual random selection of the reel stop represented by the stop index i begins with a processor 20

initiated interrupt 70. In the preferred embodiment of the invention the interrupt 70 is initiated at regular intervals by the processor 20, preferably every 60 ms for each reel 12-14. The first step in the procedure after the interrupt 70 is to randomly select at 72 a probability value represented by ΔW. The preferred parameters for ΔW will be discussed below.

At this point a recursive routine is entered beginning with a comparison at 74 of the value of ΔW to W_i less W_c. In the event ΔW is larger than this quantity, the value of W_i minus W_c is subtracted from ΔW at 76. If the value of i is less than the maximum stop index i_p as determined at 78, the value of i is incremented by 1 at 80. On the other hand, if $i = i_p$ then i is reset to 1 at 82. The next step 84 is to set the value of the residual probability W_c to zero and to return to the comparison step at 74.

This routine continues until the value of ΔW is equal to or less than W_i-W_c, whereupon the value of W_c is set equal to $\Delta W + Wc$ at 86 and the routine initiated by the interrupt 70 is excited as indicated at 88.

The procedures as illustrated in FIG. 7 will be executed at 60 ms intervals or each reel 12-14 on a continuous basis as long as the apparatus 10 is in operation. The time required to cycle through all the stop indexes $i = o$ to i_p is proportional on the average to the sum of the values of W_i in 82. At a predetermined time after a player initiated an event such as a pull on the handle 16 of FIG. 1, the current value of the stop index i is identified and it is used to stop the reel 12, 13 or 14 at the predetermined position corresponding to that index value. Over an extended period the amount of time that i remains at a particular value will on the average be proportional to the relative corresponding vaLue of the probability factor W_i. For example, if W_5 equals 2 and W_6 equals 1 then on the average i will equal 5 twice as often as it will equal 6. Thus by selecting the appropriate relative values of W_i in FIG. 6 the relative stopping frequencies of the reel stops can be predetermined. In the context of a continuously operating apparatus 10 and in particular with the routine of FIG. 7 running on a continuous basis, the handle pull can be considered a random event. Therefore, the value of i and hence the reel stop position will be selected randomly with the value of i proportional in frequency to the values of W_i.

A further randomizing factor is provided by randomly generating the probability value ΔW as shown at 72 in FIG. 7. The value ΔW will have a uniform probability distribution. Also in this embodiment of the invention the range of randomly generated values of ΔW can affect the operation of the apparatus 10. If, for example, the permitted maximum value of ΔW is too high, it can introduce a bias factor into the relative probability of the various values of i that are selected by the process of FIG. 7. On the other hand, if the maximum permitted value of ΔW is too low it might be possible for a particularly skilled player to anticipate the stopping positions of the reels 12-14. Therefore in the preferred embodiment of the invention, the maximum value of ΔW should be approximately equal to:

$$\Delta W = \frac{\sum_{i=1}^{p} Wi}{5}$$

Also, the use of the residual probability value W_c as shown at 68, 74, 76, 84 and 86 of FIG. 7 is desirable since it tends to smooth the operation of the process from one 60 ms interrupt interval to another.

As a practical matter it has been found that the procedure of FIG. 7 using the preferred range of values of ΔW and with 60 ms interrupts 70 will on the average cycle twice through all the reel stops indexes $i = 1$ through p every two seconds. Two seconds represents the average duration between handle pulls for a skilled player. Thus the second embodiment of the invention as described above will provide an essentially random selection of reel stops. Further this embodiment of the invention provides a very flexible method for adjusting the relative probability of the reels 12-14 stopping at the various reel stops.

Claims

1. A nonuniform probability reel stop mechanism for a gaming machine comprising a digital memory (24) for storing a stop index for each reel stop, and a microprocessor (20) for randomly selecting a stop index value including means for predetermining the probability of selection of each of the stop indexes.

2. A mechanism according to claim 1 in which the probability determining means includes means for generating a probability value and means for comparing the probability value to a probability factor associated with one of the stop indexes.

3. A mechanism according to claim 2 in which the microprocessor (20) includes residual means for generating a probability value, and the comparison means subtracts the residual probability value from the selected reel stop probability.

4. A mechanism according to claim 3 in which the comparison means sets the residual probability value to zero after incrementing the stop index.

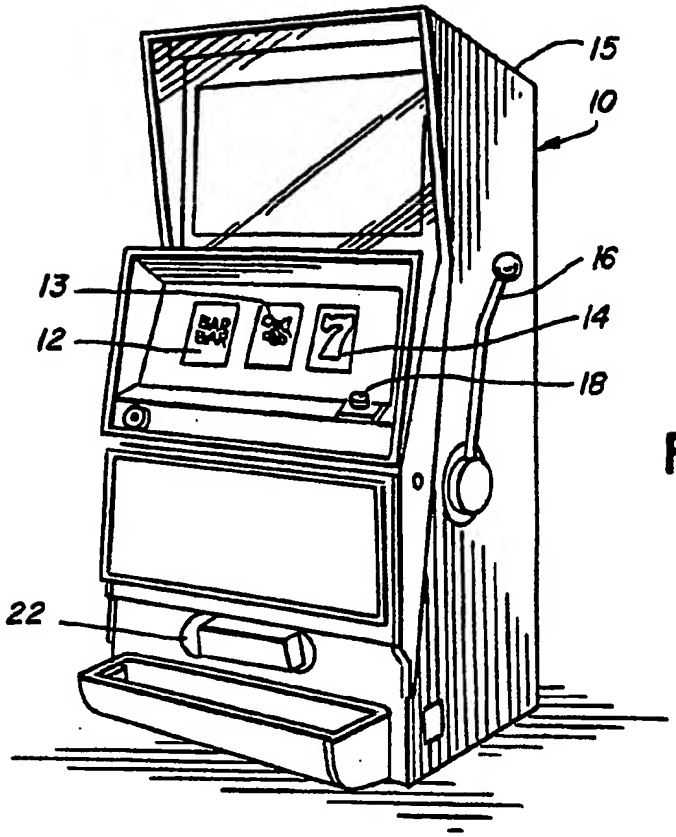
15
10
16
13
14
12
18
22

FIG. 1

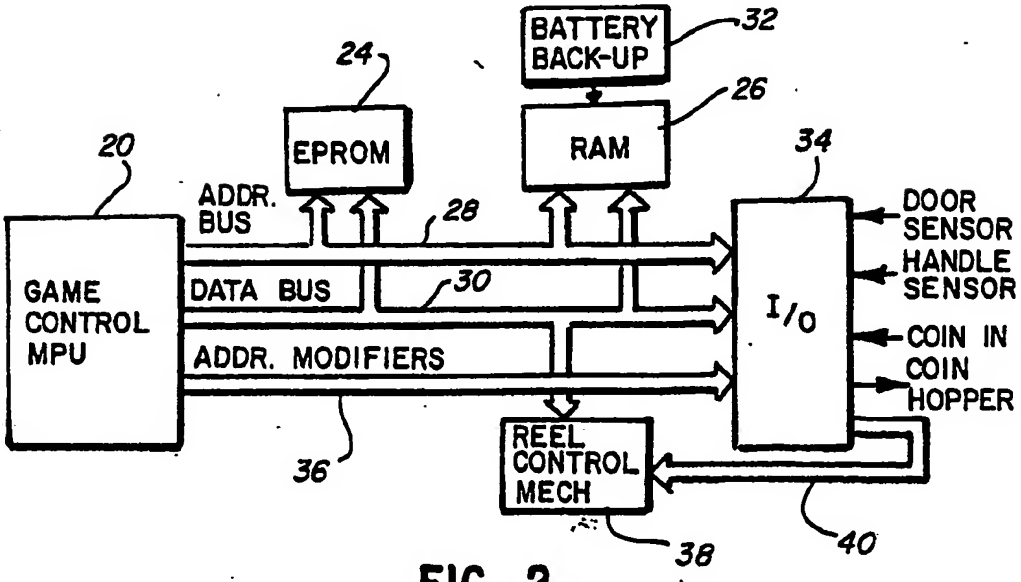
BATTERY BACK-UP
32
24
26
EPROM
RAM
20
34
ADDR. BUS
28
DOOR SENSOR
HANDLE SENSOR
GAME CONTROL MPU
DATA BUS
30
I/O
COIN IN
COIN HOPPER
ADDR. MODIFIERS
REEL CONTROL MECH
36
38
40

FIG. 2

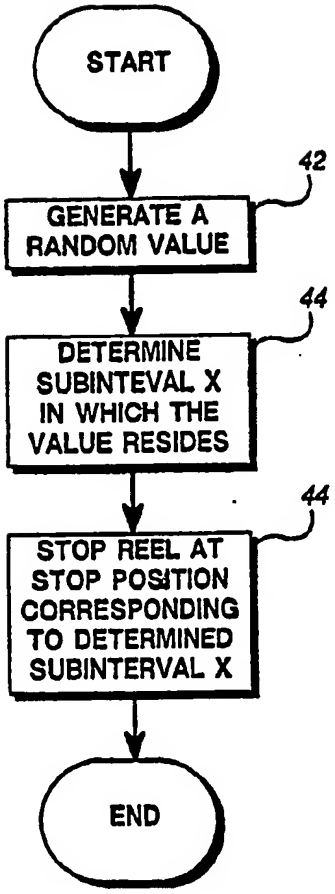
START
42
GENERATE A RANDOM VALUE
44
DETERMINE SUBINTEVAL X IN WHICH THE VALUE RESIDES
44
STOP REEL AT STOP POSITION CORRESPONDING TO DETERMINED SUBINTERVAL X
END

FIG. 3

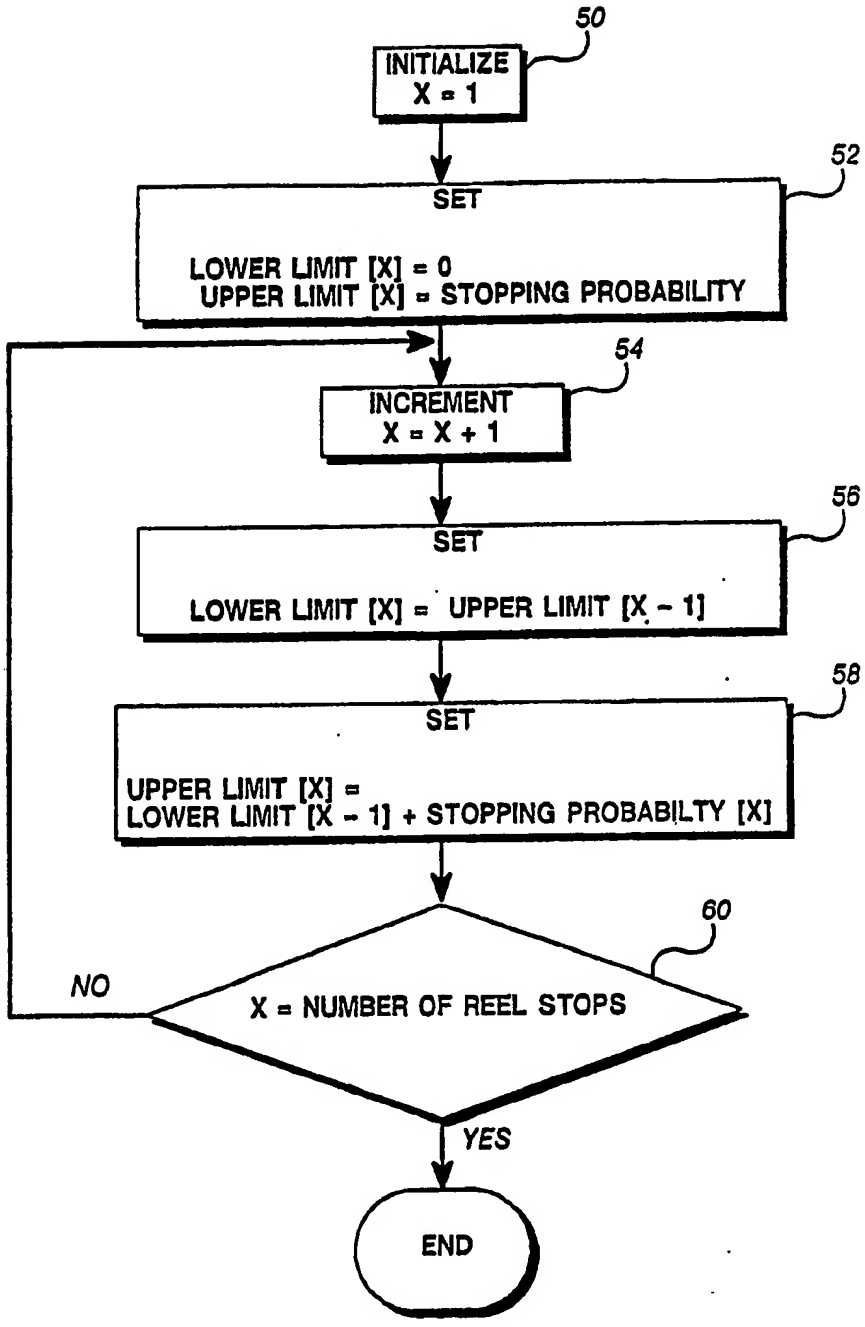
50
INITIALIZE
X = 1
52
SET
LOWER LIMIT [X] = 0
UPPER LIMIT [X] = STOPPING PROBABILITY
54
INCREMENT
X = X + 1
56
SET
LOWER LIMIT [X] = UPPER LIMIT [X - 1]
58
SET
UPPER LIMIT [X] =
LOWER LIMIT [X - 1] + STOPPING PROBABILTY [X]
60
X = NUMBER OF REEL STOPS
NO
YES
END

FIG. 4

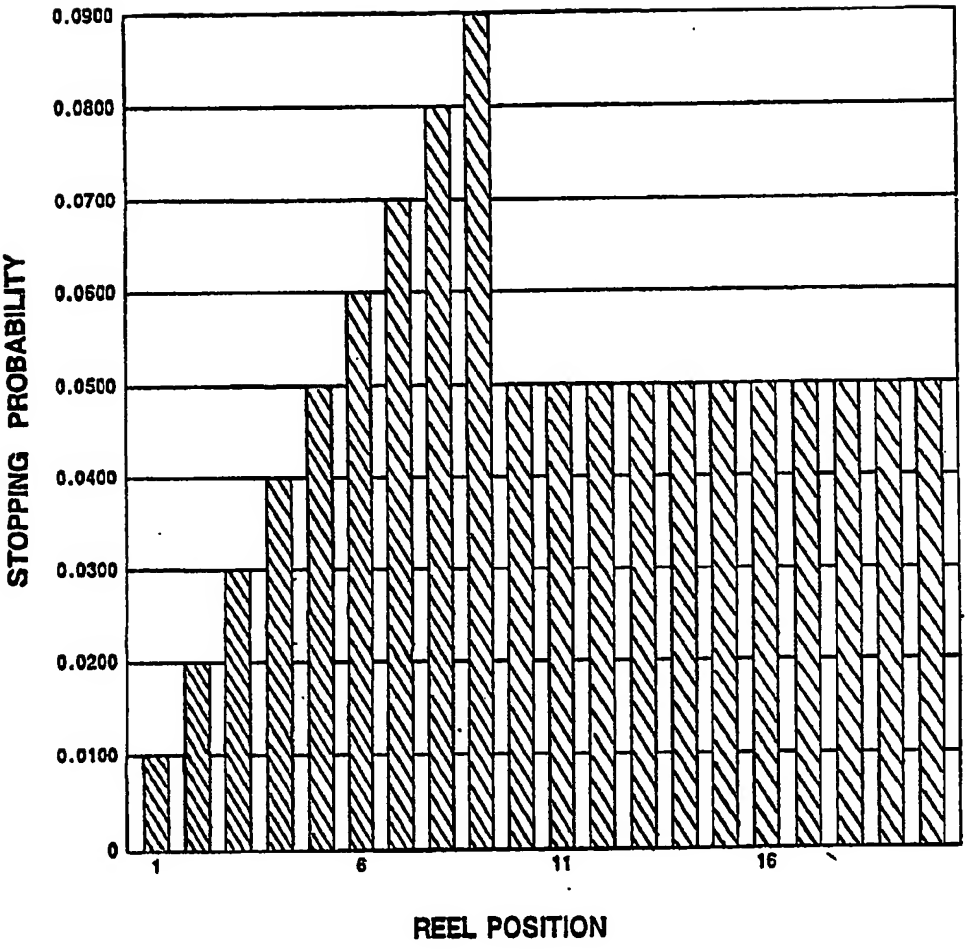
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0
STOPPING PROBABILITY
1
6
11
16
REEL POSITION

FIG. 5

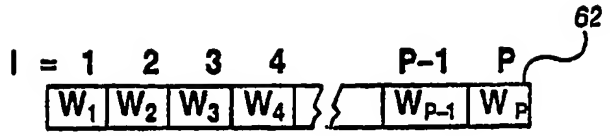
I = 1 2 3 4 P-1 P
62
W1 W2 W3 W4 WP-1 WP

FIG. 6

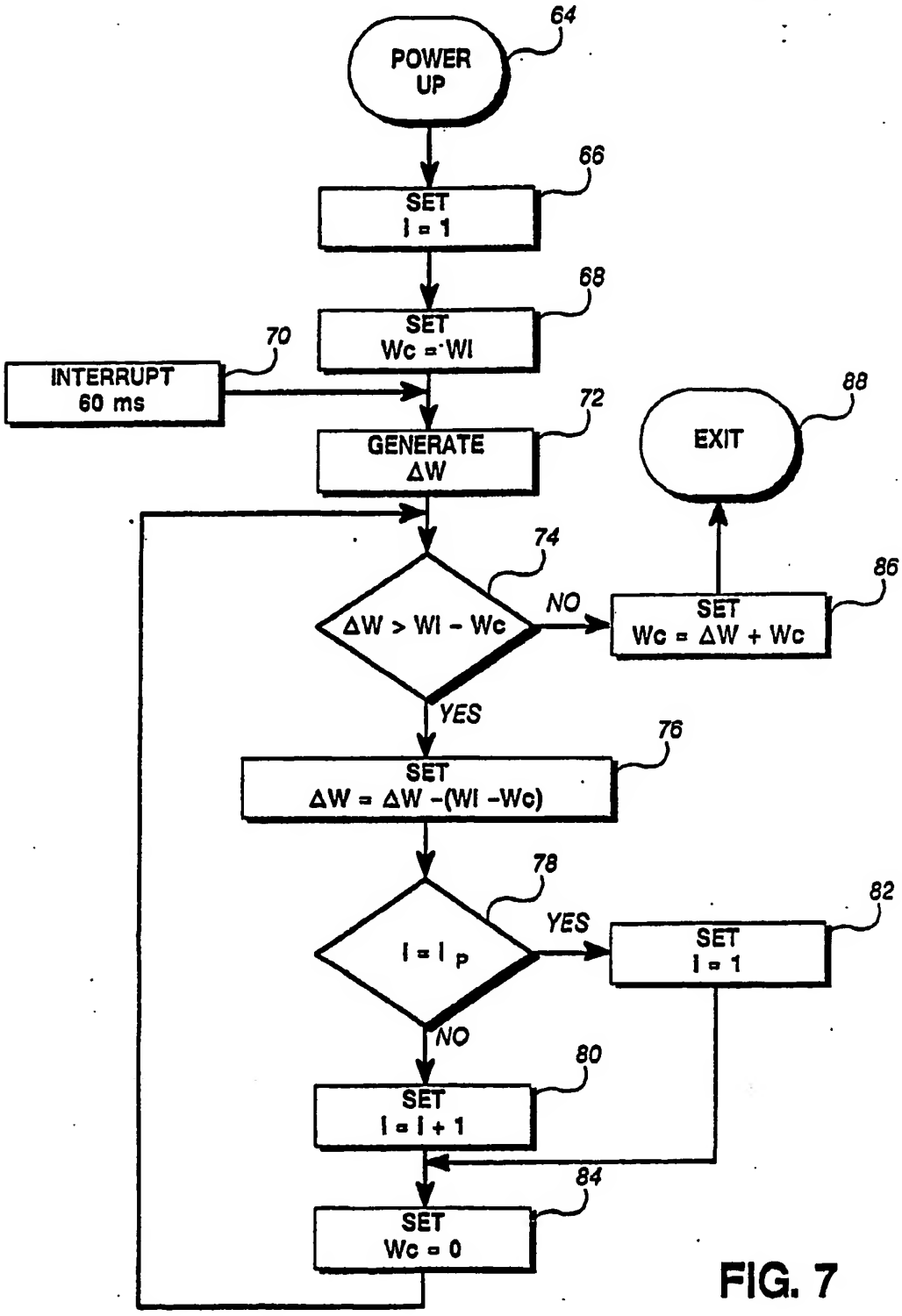
64
POWER UP
66
SET I = 1
68
SET Wc = WI
70
INTERRUPT 60 ms
72
GENERATE ΔW
74
ΔW > WI - Wc
NO
86
SET Wc = ΔW + Wc
88
EXIT
YES
76
SET ΔW = ΔW -(WI -Wc)
78
I = I P
YES
82
SET I = 1
NO
80
SET I = I + 1
84
SET Wc = 0

FIG. 7

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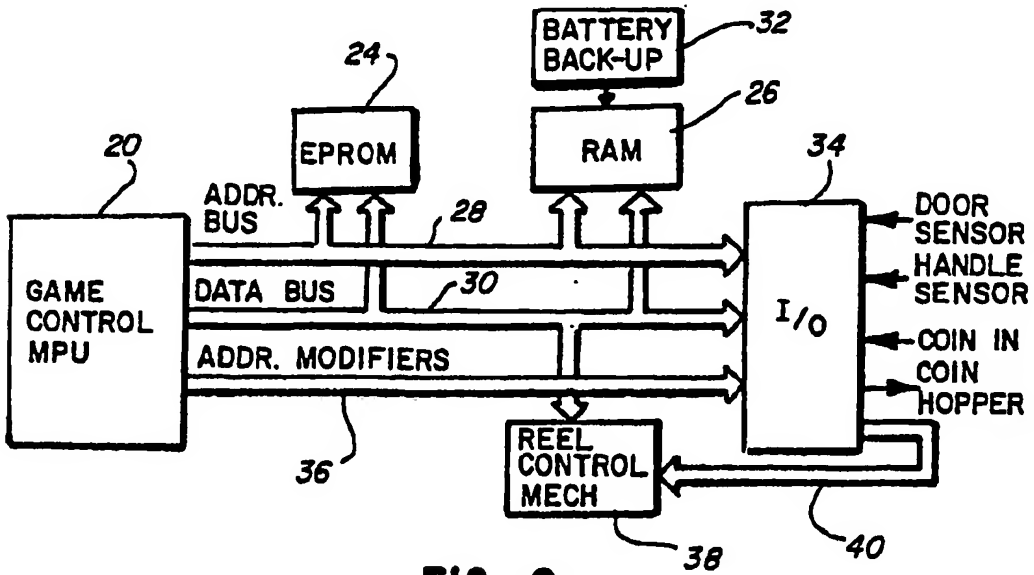

FIG. 2

EP 0 338 743 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 30 3762

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 122 138 (KABUSHIKI KAISHA UNIVERSAL) * abstract * * pages 11 - 12 *	1	G 07 F 17/34
A	EP-A-0 061 052 (GAT) * abstract; claim 6 *	1,2	
A	US-A-4 095 795 (SAXTON) * abstract * * column 2, lines 29 - 66 * * column 8, lines 47 - 55 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G 07 F

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	19 February 91	TACCOEN J-F.P.L.

CATEGORY OF CITED DOCUMENTS

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